Oithona davisae (Copepoda: Cyclopoida), A Potential Invader to the Pacific North West, A Guide to its’ Identification, Invasion Pathways, and Life History
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anteriorly, naked; flap of dorsal seta well developed, extending beyond posterodorsal margin of caudal ramus.

Head rounded or produced into pointed rostrum. Posteroventral margin of caudal ramus straight, serrate; flap of dorsal seta reduced not extending beyond posterodorsal margin of caudal ramus.

2. Swimming legs one through four with three endopodal segments. (B) ............... 3
Swimming legs one through four with two endopodal segments. ............... *Paraoithona*

3. Third exopod of swimming leg four with one to two outer marginal spines (C). First and second basal segments of antennae two with one to two outer marginal setae. ............... 4
Third exopod of swimming leg four with three outer marginal spines. First and second basal segments of antennae two without outer marginal setae. ............... *Oithona simplex*

4. Second basal segment of the mandible with one thick spine and one slender setae on Distal margin. First and second basal segments of second antennae with two moderately thick and one minute setae. ............................................................
Second basal segment of the mandible with two thick spines or two blunt hooks (D). First and second basal segments of the second antennae with two moderately thick setae only (E). ............................................................ 5
7. Rostrum sharply pointed in ventral view. (G) ..............................................8
   Rostrum rounded in ventral view .................................................................

8. Genital segment and urosome segment three with dorsal transverse rows of setules;
genital segment with lateral hairs. Distal margin of first inner lobe on Maxillae one seta
are thick, very short, and do not extend to the middle of next seta. ........................
..............................................................Oithona brevicornis
Genital segment and urosome segment three without dorsal transverse rows of setules or
lateral hairs. On the distal margin of the first inner lobe on Maxillae one seta are thick,
very long, and about three times as long as next seta. ......................................9

9. Endopod of maxillae one with one setae. (I) .................................................Oithona davisae
   Endopod of maxillae one with three setae ..................................................10

10. Exopod of maxillae one with three setae .................................................Oithona wellerhausi
    Exopod of maxillae one with four setae .................................................Oithona aruensis
8. Second basal segment of mandible with one pointed and one blunt terminal spine
   Second basal segment of mandible with two pointed terminal spines

9. Distal margin of first inner lobe of maxillae one with long seta, extending far beyond
   tip of the third inner lobe terminal seta
   Distal margin of first inner lobe of maxillae one with short seta, not extending to tip
   of the third inner lobe terminal seta

10. Endopod of maxillae one with one seta
    Endopod of maxillae one with three setae

12. Exopod of maxillae one with four setae
    Exopod of maxillae one with three setae

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**Origin and Distribution**

In 1979, California Fish and Game identified the first specimens of *O. davisae* in
San Francisco, California. Re-examined San Francisco estuary archival samples from
various sources showed that *O. davisae* inhabited the estuary since 1963. Ferrari and
Orsi put forward that *O. davisae* was not native to the San Francisco estuary because of
its taxonomic similarity to other Indo-Pacific *Oithona* species. They suspected ballast
water was the vector of introduction[2]. The introduction was most likely from Japan,
but *O. davisae* did not appear in Japanese scientific literature until 1985. A study
published in 1985, but started in 1971, determined that *O. davisae* was the most
abundant copepod in mud flats of Kyushu, Japan[4]. Subsequent studies showed that
*O. davisae* was highly abundant and native to estuaries of Japan [5-7] In studies prior to
1985, *O. davisae* was probably misidentified as *O. aruensis* or *O. brevicornis.*

After the original identification of *O. davisae* in San Francisco by Ferrari and Orsi in
1984, researchers on a zooplankton survey of southern Chilean fjords found the
cyclopoid copepod in 1983[8]. In 2000 Albert Calbet of the Institut de Ciències del Mar
cultured *O. davisae* from individuals found in Barcelona harbor[9]. The three non-native
documented locations are all major ports: San Francisco California, Barcelona Spain,
and the Aysen fjord of southern Chile, which contains the port of Chacabuco. The Los
Probability of Invasion for the Pacific Northwest

The Pacific Northwest has the fifth busiest port in North America and with shipping comes the possibility of ballast water mediated introductions[11]. A majority of the shipping traffic comes from Asian ports, specifically Japan. Besides Japan, the Pacific Northwest receives domestic transit from the San Francisco Bay Area. These two locations, native and non-native, are potential pools that can distribute *O.davisae* into the Pacific Northwest. Ballast water samples obtained from vessels entering Puget Sound, from both regions, contained *O.davisae*. The vessel densities, from a 2005-2007 dataset, ranged from zero to 39,930 individuals per cubic meter, with an average of 1,361 per cubic meter; which shows that propagule pressure from this species is high. A 2005 invasive zooplankton survey of Puget Sound waters did not find *O.davisae*(unpublished data); nor was it found in a 2001-2004 invasive species survey of the Columbia River. The Columbia River invasive species survey stated that 34% of invasive species originated from Asia and ballast water was the vector[12]. Even though researchers have not found *O.davisae* in the Puget Sound, the probability of its presence is high because of high densities in ballast water entering the Sound and *O.davisae*’s history of ballast water mediated introductions.

Life-history and basic ecology

*O.davisae* is a pelagic cyclopoid copepod. Cyclopoids have four major life phases: egg, nauplii, copepodite and adult. The naupliar and copepodite phases are separated into six stages each. *O.davisae* can be the most abundant mesozooplankton species in its’ native habitat. In inner Tokyo Bay, densities of adults and copepodites can reach 778,000 per cubic meter, but densities become dramatically lower at the mouth of the Bay[13]. Even with high densities reproductive success is hampered by high female to male sex ratios, where only one-third of females are fertilized[14] Abundances peak in December and July and can comprise 99% of the zooplankton community.
Federal, and International levels. In the Pacific Northwest, only Washington and Oregon have enacted legislation to control or treat ballast water entering the waters of the state. Enacting legislation in Washington State required exchange of ballast water in 2001 and treatment technologies by 2010 (RCW 77.120.030 and WAC 220.77.090 and 095). Oregon required vessels to exchange ballast in 2002 (ORS Chapter 783.620.992). The state laws regulate vessels involved in domestic coastwise traffic and are supplemental to Federal Ballast water laws. The National Invasive Species Act of 1990 and 1996 (NISA) contained suggested ballast water regulations for vessels coming from outside the Exclusive Economic Zone of the United States. In 2004, NISA was federally enacted and is implemented by the United States Coast Guard.

International agreements supplement the ballast water policies of the United States and the Pacific Northwest. The International Maritime Organization implements the policies of The International Convention for the Control and Management of Ships Ballast Water. The policy created in 2004 calls for port state control of ballast water and treatment technology standards. The act requires 30 signatories; however, only eight countries have signed.

Today the only method to reduce the risk of ballast water mediated invasions is ballast water exchange. Coastal waters in ballast tanks are swapped with oceanic waters, through empty refill or flowthrough methods. The theory behind exchange is that coastal organisms are unable to survive in oceanic conditions and oceanic organisms cannot tolerate salinity and temperature fluctuations in coastal environments.

Compliance with ballast water regulations is necessary to reduce the risk of *O.davisae* becoming established in the Pacific Northwest. Washington State has already implemented a ballast water-monitoring program, which looks at vessel compliance and presence of invasive species. Field monitoring for invasive zooplankton needs to be done on an annual basis, so invasions can be spotted as early as possible.

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**Current research**

**Monitoring Projects**

- (2001- ongoing) University of Washington and Washington Department of Fish and Wildlife monitor ships entering Puget Sound and the Columbia River by taking biological samples and determine if a vessel is compliant with regulations.
• (2005-ongoing) EPA bar-coding project. Taxonomic identification of zooplankton and gene sequencing, for future use with micro-array. In the future ballast samples will be genetically analyzed.

Expert contact information for PNW

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